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THE ANTERO-SUPRAGNATHAL OF *GORGONICHTHYS*

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INTRODUCTION

Newberry proposed the generic name *Titanichthys* in 1885 for the remains of a spectacularly large arthrodiran fish from the upper Devonian Ohio Shales formation. During the ensuing 60 years, bones referable to the genus have proved to be as commonly encountered in collecting throughout the northern Ohio field as are those of the various, more widely and more popularly recognized species of *Dinichthys* which occur contemporaneously in the same formation. *Titanichthys*, in consequence, has become well established as a distinctive member of the fish fauna of the Ohio Shales, and although no thorough revisionary work has been attempted for many years, six species are tentatively assigned to the genus at the present time. Despite this, the details of titanichthyid structure are still very imperfectly understood. Peculiarly modified in a bottom-feeding adaptation (Dunkle and Bungart, 1942), many of their skeletal elements are, in addition, so excessively thin that they cannot be removed from the matrix. An inability to observe either the presence or absence of the usually characteristic sensory canals and the number and nature of overlap areas by adjacent bones often makes impossible the determination, as to particular skeletal part, of isolated specimens. More important, these conditions of preservation and unfamiliar modification have led to a complete failure to recognize for *Titanichthys* any of the supragnathal elements and some of the dorsal and ventral body armoring plates.

In connection with one of these latter unsolved structural issues, the first definitive identification of the upper mouth parts of *Titanichthys* was announced by Dr. Louis Hussakof (1930) before the twenty-first annual meeting of the Paleontological Society at Washington, D. C. Unfortunately neither figures nor formal description of the specimen have subsequently appeared. A meager abstract, as the only published account of this report, has remained a source of intriguing interest to all students of the Arthrodira.

Recently, Mrs. John Bull, working among the collections of fossil fishes in the American Museum of Natural History under the direction of Dr. Edwin H. Colbert, came upon two associated bones which bear the identifying labels, respectively, of a "left antero-supra-gnathal" and indeterminate "cranial bone" of *Titanichthys*. These were submitted to and gratefully received by the present writers. Careful comparisons with the abstract indicate the bones to be those on which Hussakof based his original report. They (A.M.N.H. No. 7908) were collected by Peter A. Bungart in 1910 from exposures of the Cleveland Shale member of the Ohio Shales formation on the shore of Lake Erie, 1/2 mile east of the Avon Plant of the Cleveland Electric Illuminating Company in Avon Township, Lorain County, Ohio. The specimen is here described and figured for the first time because the characters of the supragnathal element preclude its reference to the genus *Titanichthys*, as do also those of the "cranial plate" which is revealed as a fragmentary anterolateral plate. These specimens are here referred to *Gorgonichthys*.

These writers sincerely appreciate the

[1] The Cleveland Museum of Natural History, Cleveland, Ohio.

courtesy of the officials of the American Museum of Natural History, New York, in permitting this study and for the privilege of publication in this series.

DESCRIPTION

The present specimen consists of two bones: one, a left antero-supragnathal; and the other, as here interpreted, a fragmentary right anterolateral plate. The outlines and relationships between the separate parts of these two bones are illustrated in figures 1 and 2, respectively.

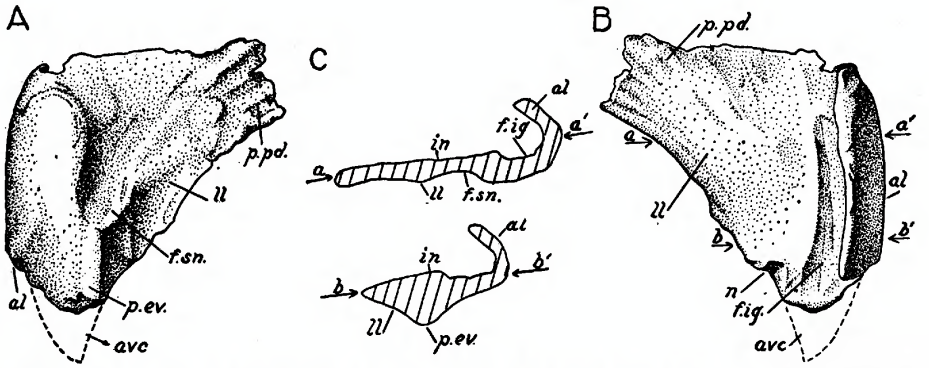

Fig. 1. *Gorgonichthys clarki* Claypole (A.M.N.H. No. 7908). Left antero-supragnathal in (A) lateral aspect, (B) mesial aspect, and (C) frontal sections. Reproduction approximately $\times 1/6$. a-a', Plane of frontal section (C) indicated on B; al, mesially directed anterior lamina of the antero-supragnathal; avc, anteroventral cusp; b-b', plane of frontal section indicated on B; f. ig., incised area worn by the anterodorsal cusp of the inferognathal; f. sn., fossa for the articulation with the subnasal element; in, internal surface of the antero-supragnathal; ll, longitudinally directed lateral lamina of the antero-supragnathal; n, notch on posteroventral margin of the element worn by the oral margin of the opposing inferognathal plate; p. ev., external vertical ridge marking the thickening of the anteroventral cusp; and p. pd., backwardly directed posterodorsal extremity of the antero-supragnathal.

The antero-supragnathal possesses an over-all length of 207 mm. The maximum depth of the element, as preserved, is 194 mm. Its ventral cusp, however, is incomplete, and the total restored height should approximate 230 mm. Typically arthrodiran in development, the plate may be said, for purposes of description, to be composed of anterior and lateral laminae which are united anterolaterally in an externally rounded angle of less than 90 degrees.

The anterior lamina, quadrangular in outline from forward view, exhibits a depth of more than three-quarters the total restored height of the bone. The width of this mesiad extension is less than one-fourth the maximum depth. The external face of the part is acutely convex in frontal section, and is also convex, although to much less degree, in any parasagittal plane. Its internal surface is concave in both of these respective sections.

The lateral lamina of the antero-supragnathal comprises the main body of the element. With regard to general shape, it is roughly triangular in either lateral or lingual views with the slightly concave posteroventral margin the longer of the three sides, and the posterodorsal angle truncated. This plate-like expanse of bone is so situated that its broad internal and external surfaces are vertically inclined. The thin, although relatively deep, posterodorsal extremity shows little mesial curvature, but is extended virtually straight backward. Anteroventrally, a stout cusp is developed whose thickening is marked by a vertical ridge, externally. Worn internally by the ventrally opposing inferognathal, the cusp is triangular in frontal section. This cusp development, in so large a plate, is restricted to a surprisingly low ventral area. Immediately

above the external vertical ridge of the thickened cusp a depression is displayed whose margins diverge dorsally across both the anterior and lateral laminae of the bone. Similar concavities occur on the antero-supragnathals, where known, of all the dinichthyid arthrodires. They mark the areas for articulation with the paired sub-nasal elements which will be fully described and determined as anterior ossifications of the primary palatoquadrate complex in a forthcoming paper by the present writers. Lingually, the surface of the lateral lamina is featureless except for a very high, narrow, and deeply incised area forward from the ventral cusp of the antero-supragnathal resulting from wear by the anterodorsal cusp of the inferognathal. Finally, the posteroventral margin of the plate is angularly notched just behind the anteroventral cusp in a manner indicative of an externally overlapping opposition upon a decidedly obtuse inferognathal oral margin.

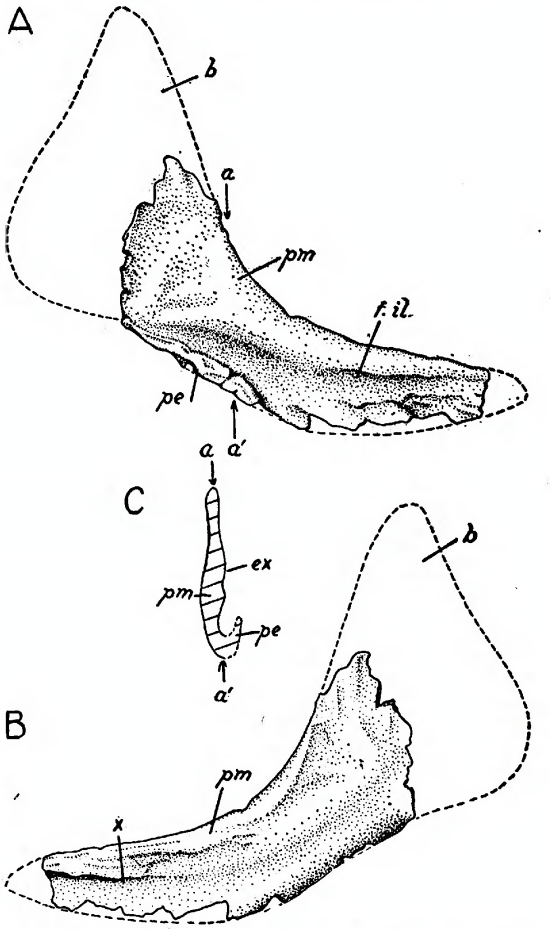

Fig. 2. *Gorgonichthys clarki* Claypole (A.M.N.H. No. 7908). Fragmentary right anterolateral plate in (A) lateral aspect, (B) mesial aspect, and (C) transverse section. Reproduction approximately $\times 1/6$. a-a', Plane of transverse section (C) indicated on A; b, restored posterodorsal expansion of the anterolateral plate; ex, external face of the element; f. il., rugose surface on the external surface of the mesial arm for the articulation of the interolateral plate; pe, lateral anteroventrally projecting arm; pm, mesial anteroventrally projecting arm; and x, unexplained rugosities on the inner face of the mesial arm.

As regards the second of the two bones comprising the present specimen, the determination of fragmentary arthrodiran bones as to particular skeletal part is often admittedly hazardous. In this case, how-

ever, the recognition of definite structures is possible, and this redetermination of the erstwhile "cranial plate" as an anterolateral element is considered of unquestionable validity.

The preserved crescentic portion represents the anteroventrally projecting limbs of an anterolateral plate of the type known to be possessed by *Gorgonichthys*, *Heintzichthys*, and *Titanichthys* (Dunkle and Bungart, 1940; Heintz, 1931). In these genera the external arm of the anterolateral elements, well developed and bearing spinal plates in *Coccosteus* and the members of the *Dinichthys terrelli* group, is reduced to a laterally upfolded flange, in varying degrees of completeness, on the ventral margin of the mesial arm. In addition, these genera invariably exhibit the rugose overlap area on the lateral face of the mesial arm which marks the articulatory surface for the interolateral plate. Both of these structural evidences are to be observed on this particular specimen, and support our convictions as to the identity of the fragment. It may be noted that the lateral arm vestige, depicted in figure 2, is very weakly developed and that the main body of the element, paralleling the concave anterodorsal margin, is only moderately thickened. At present the rugosities displayed on the inner face of the mesial arm are not explained, although they are undoubtedly concerned with the cartilaginous primary shoulder girdle. Worthy of mention, also, is the general delicate structure of this anterolateral plate compared with the truly massive and powerful dentition which the associated antero-supragnathal denotes. This apparently reflects a tendency toward the further reduction of the dorsal body armor following the phylogenetic loss, in turn, of the connection between dorsal and ventral armor, the spinal elements, and, finally, the lateral anteroventral arm of the anterolateral plates.

REMARKS

As may be gathered from the above description, the characters of the present two bones are identical with those of the corresponding elements of the genus *Gorgonichthys* Claypole (1892), as recently redefined (Dunkle and Bungart, 1940). Briefly discussed below, the most pertinent of these characters would be clearly distinguishable from *Titanichthys* even without prior knowledge of *Gorgonichthys*, and show that these bones cannot possibly be referred to the former genus.

The antero-supragnathal plate exhibits three areas of extensive wear by the opposing inferognathal element. These are: the high, short, and deeply incised area on the internal face of the bone, anteriorly; the worn inner surface of the anteroventral cusp; and the deep, square notch behind the cusp on the posteroventral margin of the plate. Assuming that functionally worn supragnathal bones must necessarily reflect functionally abraded inferognathals, the above evidences of wear would seem to indicate the oral margin of an opposing inferognathal which bore below this antero-supragnathal an acute anterior "tooth," a deep notch, and an obtuse cutting edge. These structures suit the conditions known for *Gorgonichthys*. In contrast, we have failed ever to observe conclusive evidences of functionally worn inferognathals among the titanichthyids. Further, a belief (Dunkle and Bungart, 1942) has been expressed that the inferognathal plates of *Titanichthys* have always been incorrectly interpreted—upside down and interchanged from side to side. By the proposed re-orientation, the anterior extremity of the titanichthyid inferognathal is directed ventromesially and is, in consequence, non-cuspidate orally.

As explained above, the structure of the fragmentary anterolateral plate is similar in basic pattern to that of *Gorgonichthys*, *Heintzichthys*, and *Titanichthys*. The overall dimensions of the bone, vestigial condition of the lateral anteroventrally projecting arm, and the moderate development along the longitudinal axis of the mesial anteroventral arm are details at variance with the anterolateral elements possessed by the last two genera, and definitely denote an identity with *Gorgonichthys*. We

are convinced of the correctness of the present determination for this specimen. While regrettable, it seems necessary to conclude that Hussakof's original assignment of this material was erroneous and to state that the supragnathal bones of *Titanichthys* remain unknown.

The initial proposal (Dunkle and Bungart, 1940) for the reëstablishment of the Claypole term *Gorgonichthys* was based on composite but fairly complete materials in the Cleveland Museum of Natural History, but pertained as well to all the specimens correctly referred to the *clarki* species which had been assigned to the genus *Dinichthys* by Eastman (1900) and Hussakof (1905). As stated without elaboration in that preliminary study, a number of important questions concerned with the interpretation of structure and with the phyletic relationships of the form were left unanswered. Continued study on the arthrodiran fauna of the Ohio Shales has not appreciably forwarded the solution of any of these questions. Some clarification of the problems has resulted, however, and this moment seems opportune for the statement of certain of these unsolved points regarding the status of *Gorgonichthys*.

In brief survey, the few attempts at reconstruction of the phylogeny of the Ohio Shales Arthrodira have been based primarily on the characteristics of the gnathal elements, and of these the inferognathal plates have been used most widely. From the tentative groupings of forms that have been discussed in the literature, one gains the impression that the principal development among the typical dinichthyid arthrodires proceeded from older forms in the lower Huron Shale member of the formation with obtuse cutting-edged, posteriorly denticulate inferognathals of the *Dinichthys herzeri* type to culminating forms in the upper Cleveland Shale member with acute cutting-edged, posteriorly nondenticulate inferognathals of the *D. terrelli* type. In this arrangement, the inferognathals of the *clarki* species with excessively high anterior cusp, short, blunt cutting edge, and massive, posterior "denticles" and those of *Heintzichthys* with low anterior cusps, long, blunt cutting edge, and no posterior "denticles" were considered aberrant Cleveland Shale derivatives of the Huron Shale *herzeri* type. Hussakof (1906) suggested the possibility that the blunt and acute cutting-edged inferognathal types represented two distinct developmental lines throughout the Ohio Shales formation, but discarded the theme in favor of the above pattern. An arbitrary practice thus obtained, by which the *D. terrelli*-like forms were restricted to the Cleveland Shale and any dinichthyid specimen found in the Huron Shale was automatically referred to *D. herzeri*.

This usage is no longer tenable. A gradual accumulation of more complete specimens has resulted through years of collecting. These, when studied in the light of the excellent advances made by our European colleagues in the fundamental interpretation of arthrodiran structure, have shown that the inferognathal elements merely express conditions of basic modification whose explanations must be found in other, associated skeletal parts.

In the above regard and based solely on the characteristics of the inferognathal plates, the more common dinichthyid arthrodires from the Ohio Shales appear separable into two groups. The first, which may be called the *Dinichthys herzeri* group, exhibits obtuse cutting-edged mandibular elements and includes, in addition to *D. herzeri*, *Gorgonichthys clarki*, *Heintzichthys gouldii*, and *Holdenius holdeni*. The second, here referred to as the *Dinichthys terrelli* group, possesses acute cutting-edged lower mouth parts, and includes, besides *D. terrelli*, the species *intermedius* and *curtus*.

With the exception of *Holdenius* in which the upper mouth parts remain unknown, the *herzeri* group all possess antero-supragnathal elements whose posterodorsal extremities are thin, high, and directed straight backward. In contradistinction, the posterodorsal extremities of the antero-supragnathals of the *Dinichthys terrelli* group are mesially recurved and greatly expanded. The significance of this feature has previously been touched on (Dunkle and Bungart, 1940) and is here illustrated in figure 3. Reminiscent of the relations

in acanthodians between the five small anterior ossifications with the anterior basal plate (Watson, 1937), the five supragnathal elements of certain dinichthyid arthrodires (single mediognathal, and paired antero-supragnathals and postero-supragnathals) are intimately associated with a parasphenoid-like plate in the ventral cranial basis. This latter bone, previously remarked by Hills (1936) for *Coccosteus*, by Stensiö (1934; 1945) for various other arthrodires, and completely described for *Dinichthys terrelli* in a forthcoming paper by us, is apparently to be homologized with the anterior basal element of the acanthodians. This element in *D. terrelli* is thickened anteromesially and its forward margin excavated by a pair of deep concavities. From a correct alinement of all associated elements, the expanded posterodorsal extremities of the *terrelli* type of antero-supragnathal are indicated to have had a direct abutting articulation into these pits. In contrast, as known for at least one of the *herzeri* group, *Heintzichthys gouldii*, the anterior portion of the anterior basal plate is a proportionately much narrower, thin lamina of bone, strongly arched dorsally. From observations on reconstructed specimens, the flange-like posterodorsal extremities of the *Heintzichthys* antero-supragnathal could not have had any direct articulation with that member, but apparently possessed a type

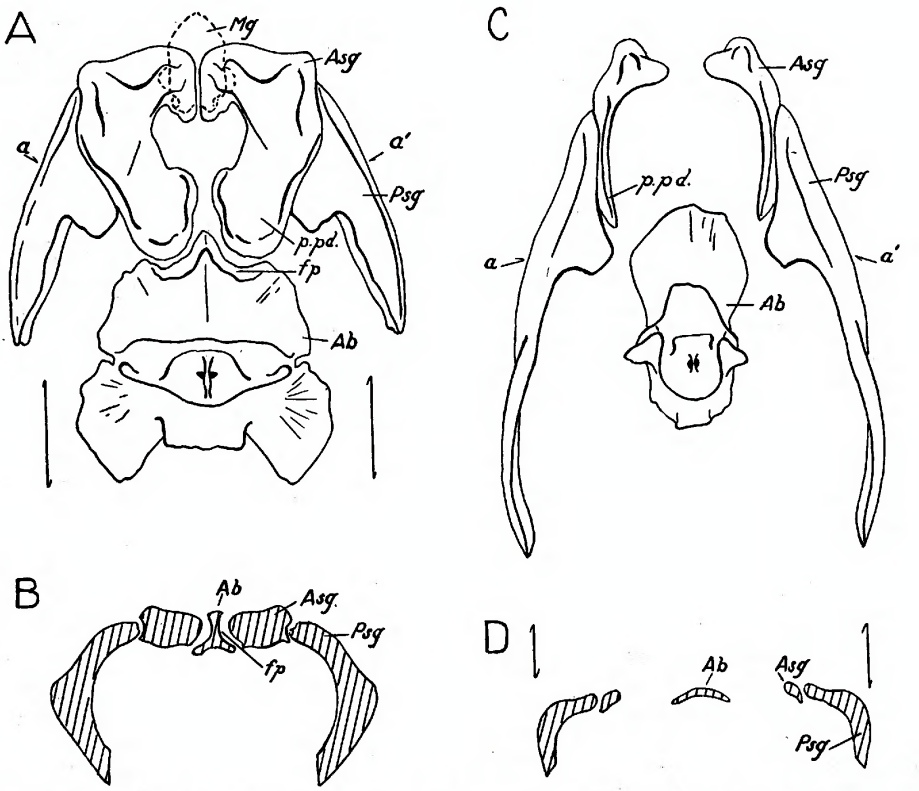

Fig. 3. Diagrams showing the arrangement of the supragnathal elements and anterior basal plate in dorsal aspect and in transverse section of (A and B, respectively) *Dinichthys terrelli* and (C and D, respectively) *Heintzichthys gouldii*. Reproduction of A and B approximately $\times 1/6$; and of C and D approximately $\times 2/3$. a-a', Planes of the transverse sections (B and D) indicated on A and C; Ab, anterior basal plate; Asg, antero-supragnathal plate; fp, concavities on the forward margin of the anterior basal plate; Mg, mediognathal plate superimposed in dashed lines in A but omitted on C; p. pd., posterodorsal extremity of the antero-supragnathal plate; and Psg, postero-supragnathal element.

of overlapping arrangement, only, however, through the intermediary of a wide expanse of the cartilaginous braincase floor.

In addition to the above differences of gnathal and endocranial structures between the *terrelli* and *herzeri* groups, two of the designated members of the latter, *Gorgonichthys clarki* and *Heintzichthys gouldii*, possess in common a number of fundamental characteristics which are at wide variance with the corresponding structures of the *terrelli* group. These are: cranial shields lacking the massive transverse and longitudinal ventral thickenings, possessing proportionately larger orbital emarginations, indistinct postorbital processes, and relatively much shorter postero-lateral marginal extent; reduced ventral keels on the mediodorsal plates; only vestigial lateral anteroventral arms on the anterolateral bones; apparent complete loss of spinal elements; and general reduction of the spinal processes of the antero-ventrolateral plates as well as of the entire ventral armor.

It may be remarked that comment on the modifications of the cranial shield and body armor of *Dinichthys herzeri* has been omitted in the above discussion. This has been a deliberate omission. Acute cutting-edged inferognathal plates which can pertain only to some member of the so-called *terrelli* group are frequently encountered in the Huron Shale. In fact, all the skeletal parts of the *terrelli* group exhibit so uniform and distinctive a combination of characteristics that in the opinion of these writers the vast majority of all known Huron Shale dinichthyid specimens must belong to the *terrelli* group. This fact would extend the geologic range of the *terrelli* group throughout the Ohio Shales formation, and necessitates the implication that *D. herzeri* is to be considered a rather rarely collected Huron Shale form whose dermal armor, except for the mouth parts, has not been recognized. Thus, in the absence of entirely complete specimens for the several designated members of the *herzeri* group, inference has been freely but necessarily employed in establishing the criteria for both the separation of the common Ohio Shales dinichthyids into the *terrelli* and *herzeri* groups, and the demonstration that the *herzeri* group constitutes a natural unit. The common possession of basically similar gnathal elements need not mean that *D. herzeri* and *Gorgonichthys clarki* will prove to have anterior basal plates identical with those of *Heintzichthys gouldii*, and the cranial shield and body armor of *D. herzeri* need not exhibit the comparable modifications of those common to *G. clarki* and *H. gouldii*. However, the structure of the antero-supragnathal of *D. herzeri*, which militates against the conception of any arrangement of parts similar to that of the *terrelli* group, and the regular possession in all members of the *herzeri* group of certain comparable structural developments quite prohibit the dismissal of the present phylogenetic suggestions without serious consideration.

The above considerations reflect the admitted uncertainties with which *Gorgonichthys clarki* must still be regarded. The *clarki* species is without doubt generically distinct from the members of the so-called *terrelli* group. However, the as yet incompletely revealed *herzeri* species, from which *G. clarki* is presumably derived, is the genotype of *Dinichthys*. Until *D. herzeri* is more adequately understood, the removal of the *clarki* species from the genus *Dinichthys* and the proposal for the re-establishment of the term *Gorgonichthys* for its reception are based on inconclusive evidence. Despite this, the provisional recognition of the *clarki* species as a distinct morphological type is advocated by us because of the peculiar modifications of its skeletal complex and the measurable differences between its gnathal elements and those of *D. herzeri*. These latter structural adaptations are, in part, illustrated by the following attempted analysis of the jaw mechanism.

The gnathostomous character of placoderm jaws has been established through many recent studies by Gross, Heintz, Stensiö, Watson, and others. Based on these fundamental interpretations the present writers have determined that the first visceral arch among the dinichthyid arthrodires ossified in four centers. The antero-inferognathal and postero-infero-

gnathal represent, respectively, anterior and posterior ossifications of the Meckelian segment of the arch. The presumed dermal inferognathal plate is borne dorsally astride with its anterior end lateral and its posterior extremity mesial to these primary mandibular elements. The sub-nasal bone, referred to above, and the post-suborbital element represent, respectively, anterior and posterior ossifications of the dorsal palatoquadrate portion of the arch. Similarly, thickened protuberances on the lateral face of the postero-inferognathal and on the inner face of the post-suborbital seem to indicate a movable articulation between these two elements, and liken them to articular and quadrate, respectively. Some evidences exist (Dunkle and Bungart, 1945) that the sub-nasal and post-suborbital were connected in life by a lamina of cartilage. In *Dinichthys terrelli* this cartilage must have extended, vertically inclined, mesial to the ventrolateral borders of the marginal plate, posteriorly, and to have occupied, horizontally inclined, the prominent groove on the mesial surface of the "handle" portion of the suborbital element, anteriorly. In this forward part it would then have served as a strengthening support dorsolaterally for the supragnathal elements which dorsomesially were embedded in the cartilaginous braincase floor. From these homologies it may be postulated that the adductor muscles, originating on the ventrolaterally expanded marginal plate, passed downward toward their insertion on the inferognathals, mesial to the suborbital check plate and lateral or structurally dorsal to the restored palatoquadrate cartilage. The lengths of the posterior blade portions of both the suborbital and inferognathal plates as well as the length of the lateral margin of the cranial shield from postorbital process to postmarginal tip may thus be considered indices of the length of the space occupied by the adductor muscles, as well as of the relative mechanical efficiency of the lever-like jaws. Some approximation to the cross-sectional area of these muscles may be approached through the projection of the ventrolateral expansion of the marginal bone, from which the muscles originate, in reconstructed specimens where all elements are oriented in correct relationship to one another.

The distinctive modifications of *Gorgonichthys clarki* may be demonstrated by an application of the above considerations. For purposes of comparison the reconstructed heads of *Dinichthys terrelli*, *Gorgonichthys clarki*, and *Heintzichthys gouldii*, all reduced to a unit size, are shown in figure 4.

In *Dinichthys terrelli* it may be noted that the orbit is small. Its length is contained five and one-half times in the greatest lateral length of the cranial shield from the plane of the rostral tip to the hindermost limit of the postmarginal plate. The marginal length of the shield from postorbital process to postmarginal extremity is thus the longest such dimension attained by any of the Ohio Shale arthrodires. This great length is reflected in the lengths of the posterior blade portions of both its suborbital and inferognathal elements. Similarly the ventrolateral expansion of the marginal plate is proportionately tremendous. The restored cross-sectional area of the adductor muscles was in consequence large and indicative of massive muscles. The fiber length was also relatively longer. This fact is shown by the more feeble extension of the posterolateral wings of the cranial shield, the depth of the vertically expanded blade part of the suborbital, and the degree of upward arching of the posterior blade portion of the inferognathal plate. The jaw mechanism must therefore be considered as both powerful and fast, and the *terrelli* group, with their acute cutting-edged mouth parts, consequently appear to have been the most formidable of the upper Devonian predators.

In contrast, the orbits of both *Gorgonichthys clarki* and *Heintzichthys gouldii* are much enlarged. Their lengths are contained two and one-half times and twice, respectively, in the greatest lateral length of the cranial shield. The marginal length, therefore, from which the adductor muscles originate is much reduced. The ventrolateral expansion of the marginal is correspondingly small. The restored cross-sectional area indicates much smaller

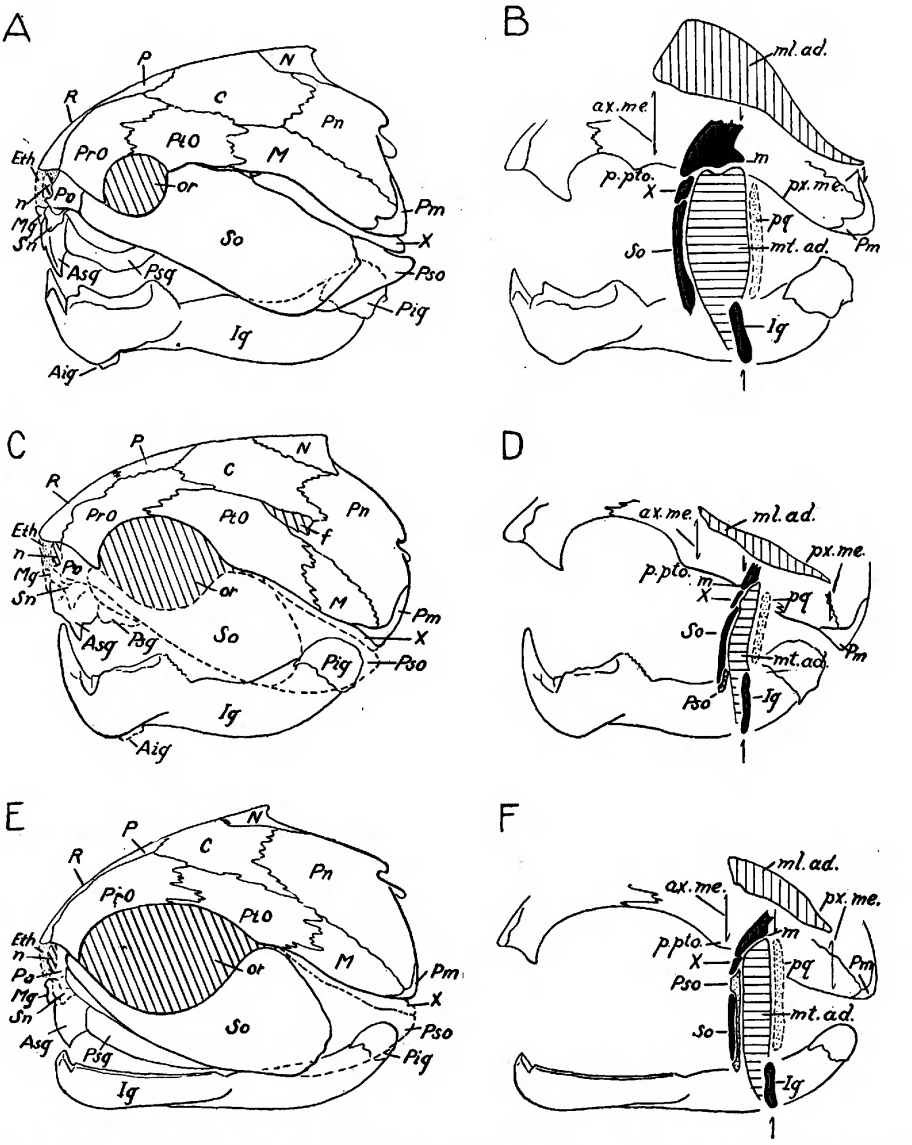

Fig. 4. Attempted restorations of the heads and of transverse sections through the cheek regions of (A and B, respectively) *Dinichthys terrelli*, (C and D, respectively) *Gorgonichthys clarki*, and (E and F, respectively) *Heintzichthys gouldii* to show the degree of variation in the proportions of homologous parts. In B, D, and F presumed dermal bone is indicated by solid black, cartilage and primary ossifications by stipples, and muscle sections by hachuring. Figures are all reduced to a unit size: that of *Dinichthys* being approximately $\times 1/14$; *Gorgonichthys*, $\times 1/12$; and *Heintzichthys*, $\times 1/6$, of average-sized specimens. Aig, antero-inferognathal plate; Asg, antero-supragnathal plate; ax. me., anterior limit of the ventrolateral expansion of the marginal plate; C, central; Eth, restored extremity of the ethmoidal cartilage; Ig, inferognathal; M, marginal; m, expanded ventrolateral edge of the marginal plate; Mg, mediognathal; ml. ad., frontal section through the restored adductor muscles; mt. ad., transverse section through the restored adductor muscles; N, nuchal plate; n, external nare; or, orbit; P, pineal plate; Pig, postero-inferognathal; Pm, postmarginal; Pn, paranuchal; Po, postnasal; p. pto., postorbital process; pq, restored palatoquadrate cartilage; PrO, pre-orbital; Psg, postero-supragnathal; Pso, post-suborbital; PtO, postorbital; px. me., posterior limit of the ventrolateral expansion of the marginal plate; R, rostral; Sn, sub-nasal plate; So, suborbital plate; and X, sub-marginal plate.

muscles than those possessed by the *terrelli* group. Shorter fiber length is also indicated by the greater extension of the posterolateral wings of the cranial shield and low suborbital blades in both genera. Interestingly, the decrease in mechanical efficiency of the jaw mechanism and these apparent losses in both power and speed of the muscles were, however, compensated for in two distinct adaptations. *Heintzichthys*, on the one hand, with relatively larger muscles than *Gorgonichthys*, reduced the anterior cusp of the inferognathal and the proportionate size of the antero-supragnathal. In return, the functional lengths of its postero-supragnathal and opposing oral margin of the inferognathal were increased. *Gorgonichthys*, on the other hand, with proportionately the smallest muscles of the three genera discussed, reduced the length of the inferognathal part functionally opposed to the postero-supragnathal and increased both the size of the antero-supragnathal and the height of the inferognathal anterior cusp. This modification in attempting to concentrate all of the available force of weak muscles into one magnified point made *Gorgonichthys* a veritable "saber-toothed" arthrodire.

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